Alkalinity Protocol

Purpose

To measure the alkalinity of a water sample

Overview

Students will use an alkalinity kit to measure the alkalinity in the water at their hydrology site. The exact procedure depends on the instructions in the alkalinity kit used.

Student Outcomes

Students will learn to,

- use an alkalinity kit;
- examine reasons for changes in the alkalinity of a water body;
- explain the difference between pH and alkalinity;
- communicate project results with other GLOBE schools;
- collaborate with other GLOBE schools (within your country or other countries); and
- share observations by submitting data to the GLOBE archive.

Science Concepts

Earth and Space Science

Earth materials are solid rocks, soils, water and the atmosphere.

Water is a solvent.

Each element moves among different reservoirs (biosphere, lithosphere, atmosphere, hydrosphere).

Physical Sciences

Objects have observable properties.

Life Sciences

Organisms can only survive in environments where their needs are met.

Earth has many different environments that support different combinations of organisms.

Humans can change natural environments.

All organisms must be able to obtain and use resources while living in a constantly changing environment.

Scientific Inquiry Abilities

Use a chemical test kit to measure alkalinity.

Identify answerable questions.

Design and conduct scientific investigations.

Use appropriate mathematics to analyze data.

Develop descriptions and explanations using evidence.

Recognize and analyze alternative explanations.

Communicate procedures and explanations.

Time

15 minutes

Quality Control Procedure: 20 minutes

Level

Middle and Secondary

Frequency

Weekly

Quality Control Procedure: twice a year

Materials and Tools

Alkalinity test kit

Hydrology Investigation Data Sheet

Making the Baking Soda Alkalinity Standard Lab Guide (optional)

Alkalinity Protocol Field Guide

Distilled water in wash bottle

Latex gloves

Safety goggles

For Quality Control Procedure, the above plus:

- Alkalinity standard
- *Hydrology Investigation Quality Control Procedure Data Sheet*
- *Quality Control Procedure for Alkalinity Lab Guide*

Preparation

Suggested activities: *Practicing Your Protocols: Alkalinity (e-guide only)*

Prerequisites

Discussion of safety procedures when using chemical test kits

Welcome | Introduction | Protocols | Learning Activities | Appendix

Alkalinity Protocol – Introduction

Alkalinity and pH are properties of water that are related, but different. Alkalinity is the measure of the pH buffering capacity of the water. pH, on the other hand, is the acidity of water. (refer to *pH Protocol*). pH is a very important water quality parameter. Many plants and animals have very specific pH requirements and are harmed by sudden pH changes or extreme pH values. What happens to the pH of your water if acid is added? The answer depends on how much alkalinity is in the water and how much acid is added.

Alkalinity is expressed as the amount of calcium carbonate ($CaCO_3$) in your water, although other substances can contribute to alkalinity as well. The units of alkalinity are either part per million (ppm) or mg/L. These units are equivalent, as 1 ppm = 1 mg/L.

Let us say your water has a high alkalinity. When acid is added to the water, the alkalinity *neutralizes* the acid. Some of the alkalinity will be used up, so that alkalinity will go down. If more acid is added, the alkalinity will continue to decrease. Eventually, when the alkalinity is low enough, adding acid will cause the pH to decrease.

When water has high alkalinity, we say that it is *well buffered*. It resists a decrease in pH when acidic water, such as rain or snowmelt, enters it. Alkalinity comes from dissolved rocks, particularly limestone ($CaCO_3$), and soils. It is added to the water naturally as water comes in contact with rocks and soil. Water dissolves the $CaCO_3$, carrying it into streams and lakes. Lakes and streams in areas rich in limestone bedrock will tend to have a higher alkalinity than those in regions with non-carbonate bedrock.

If water has an alkalinity below about 100 mg/L as $CaCO_3$, it is *poorly buffered* and *pH sensitive*. A big rainfall or snowmelt event could add enough acid to lower the pH in a sensitive system. This could be harmful to the plants and animals that live there, particularly at certain times of the year (e.g., when fish or insect larvae are hatching).

Teacher Support

Advance Preparation

The *Practicing Your Protocols: Alkalinity Learning Activity*, will help students understand the variables that may affect their measurements.

Perform the Quality Control Procedure if it has not been done within six months.

Measurement Procedures

These kits are based on the technique of adding a pH sensitive color indicator to the sample and then adding an acid titrant solution drop by drop until a color change is observed.

There are a number of techniques the students should follow to take quality data.

1. Have the students read the directions before they begin to make sure they understand the procedure.
2. Measure carefully. Read the volume of the sample in the sample bottle at eye level Read at the bottom of the meniscus.
3. If using a titrator, make sure that the titrator is being read correctly. Most kits include instructions for the proper use of titrators. Make sure the students are familiar with the units on the titrator.
4. If the alkalinity kit uses drops, hold the dropper bottle vertically so that all of the drops are the same size.
5. During the Quality Control Procedure and actual water testing, be sure to note the color change that gives the correct alkalinity. In many kits, it is an intermediate color change that gives the correct alkalinity and not the final color. For kits with an intermediate color (such as a LaMotte kit), if you are not sure when the intermediate color change occurs, read the titrator or write down the number of drops when you think it might be first occurring. For kits with only one color change during titration, add one more drop to see if the color changes further. If it does not, use the previous number you wrote down.

Quality Control Procedure

For the Quality Control Procedure, you may make your own baking soda standard (*Making the Baking Soda Alkalinity Standard Lab Guide*). Alternatively, you may purchase a ready-made alkalinity standard solution. Please make sure to note which standard you are using in the *Hydrology Quality Control Procedure Data Sheet.*

The alkalinity of the baking soda standard is approximately 84 mg/L. It is the sum of the true alkalinity of the baking soda added (70 mg/L) plus the alkalinity of the distilled water used (usually 14 mg/L or less):

70 mg/L + 14 mg/L = 84 mg/L.

The purity of distilled water available worldwide varies significantly. As a result, its alkalinity is also variable. Unfortunately, most alkalinity test kits are not capable of producing accurate measurements for samples of very low alkalinities (i.e., less than 30 mg/L). As a result, it is very difficult to determine the actual alkalinity of your distilled water and therefore the alkalinity of your baking soda standard solution. To account for this, the actual measurement of your baking soda standard should be 84 mg/L ±10 mg/L. If the alkalinity of your baking soda standard is measured to be less than 74 mg/L or greater than 94 mg/L, prepare a new standard making sure your weights and dilutions are accurate. If you are still off by more than ±10 mg/L, you may need to replace the reagents of your test kit.

Ready-made alkalinity standards have a precisely known alkalinity. During the Quality Control Procedure, your resultant measurement should be the actual alkalinity of your standard plus or minus the maximum acceptable difference for your test kit.

Alkalinity Kit Precisions

Different alkalinity test kits have different precisions. Below are values for the maximum acceptable differences for some common test kits.

LaMotte	± 8 mg/L
Hach	± 6.8 mg/L (Low Range, 0–10 mg/L)
	± 17 mg/L (High Range, 0-50 mg/L)

If your alkalinity test kit is not listed in the table above and you are not certain how to determine the precision of your kit, please contact your GLOBE Country Coordinator or the GLOBE Help Desk and provide them with the manufacturer and model of your kit.

Safety Precautions

- Students should wear gloves when handling chemicals and water that may contain potentially harmful substances.
- Students should wear goggles when working with chemicals.
- Local authorities should be consulted on the proper disposal of used chemicals.

Supporting Protocols

pH: Alkalinity is directly related to pH; waters with higher alkalinity are more resistant to changes in pH from the influx of acid. It is, therefore, important to collect accurate pH data to compare with your alkalinity data.

Atmosphere: Atmosphere measurements, especially precipitation and temperature, are also important for interpreting your alkalinity data. Heavy rain or snowmelt, resulting in an influx of large amounts of freshwater to the system, may decrease your water's alkalinity.

In addition, knowing the geology and soil types of your area may be important for interpreting your alkalinity data.

Helpful Hints

- If your students are using multiple kits, mark the items in each kit with a dot of the same color. Use a different color for each kit. This will help avoid kit contamination by exchanging chemicals or titrators between kits.

Instrument Maintenance

1. The alkalinity kit should be kept in a dry place away from direct heat.
2. All chemicals should be kept tightly capped.
3. Chemicals in the kits should last a year if they are not contaminated, and are stored in a dry area away from extreme heat.
4. The alkalinity standard should be kept refrigerated after opening and discarded after one year.
5. Store the titrator with the plunger removed to avoid the rubber end sticking in the tube.

Questions for Further Investigation

What is the relationship between changes in pH and changes in alkalinity at your site?

How might the type of rocks and soil in your watershed affect the alkalinity of your water site?

What factors in your environment do you think might cause a change in the alkalinity at your site?

Making the Baking Soda Alkalinity Standard

Lab Guide

What You Need

- ❑ Baking soda (1.9 g)
- ❑ Balance
- ❑ 500-mL graduated cylinder
- ❑ Distilled water
- ❑ Stirring rod
- ❑ 100-mL graduated cylinder
- ❑ Pen or pencil
- ❑ 500-mL beaker

In the Lab

1. Weigh out 1.9 g baking soda and add it to the 500-mL graduated cylinder.
2. Pour distilled water into the cylinder with the baking soda to the 500-mL mark.
3. Pour this baking soda solution into the 500-mL beaker, and stir it with a stirring rod to make sure all of the baking soda has dissolved.
4. Rinse the 500-mL graduated cylinder with distilled water. Measure 15 mL of baking soda solution with the 100-mL graduated cylinder and pour it into the clean 500-mL graduated cylinder.
5. Add distilled water to the solution in the 500-mL graduated cylinder to the 500-mL mark.
6. This solution is your standard and has an alkalinity of approximately 84 mg/L.

Quality Control Procedure for Alkalinity

Lab Guide

Task

Check the accuracy of your alkalinity kit. Practice using the alkalinity test kit correctly.

What You Need

- ❏ *Hydrology Quality Control Data Sheet*
- ❏ Alkalinity test kit
- ❏ Alkalinity standard (A standard may be purchased or you can mix a standard following the *Making the Baking Soda Alkalinity Standard Lab Guide*.)
- ❏ Distilled water in wash bottle
- ❏ Goggles
- ❏ Pen or pencil
- ❏ Latex gloves
- ❏ 100-mL graduated cylinder

In the Lab

1. Put on the gloves and goggles
2. Fill in the top part of the *Hydrology Quality Control Data Sheet*. Make sure to note the type of alkalinity standard you are using, as well as your kit's manufacturer and model number.
3. Measure the alkalinity of your standard solution following your kit's directions.

   Note: Use the alkalinity standard as your water sample.
4. Record the results on the *Hydrology Quality Control Data Sheet*.
5. Compare your results with the value of your alkalinity standard:
   - if you using the baking soda standard, your results should be 84 mg/L ± 10 mg/L.
   - if you are using a ready-made standard, your results should be the actual alkalinity of your standard plus or minus the maximum acceptable difference for your test kit.

Maximum acceptable differences for common alkalinity test kits

LaMotte	± 8 mg/L
Hach	± 6.8 mg/L (Low Range, 0–10 mg/L)
	± 17 mg/L (High Range, 0-50 mg/L)

6. If your measured values are not within the expected range, try doing the procedure again using a fresh standard sample.
7. If your value is still not within range, discuss possible problems with your teacher.

Alkalinity Protocol
Field Guide

Task
Measure the alkalinity of your water sample.

What You Need
- ❑ *Hydrology Investigation Data Sheet*
- ❑ Alkalinity test kit
- ❑ Gloves
- ❑ Distilled water in wash bottle
- ❑ Goggles
- ❑ Pen or Pencil

In the Field
1. Fill out the top portion of your *Hydrology Investigation Data Sheet*.
2. Put on the gloves and goggles
3. Follow the instructions in your alkalinity kit to measure the alkalinity of your water.
4. Record your measurement on the *Hydrology Investigation Data Sheet* as *Observer 1*.
5. Repeat the measurement using fresh water samples.
6. Record as *Observers 2* and *3*.
7. Calculate the average of the three measurements.
8. Each of your individual measurements should be within the acceptable range of the average.

Maximum acceptable differences for common alkalinity test kits

LaMotte	± 8 mg/L
Hach	± 6.8 mg/L (Low Range, 0–10 mg/L)
	± 17 mg/L (High Range, 0-50 mg/L)

9. If one measurement is outside this range, discard that measurement and find the average of the other two.
10. If they are still in range, report only the two measurements.

Frequently Asked Questions

1. How can I be sure when the color change has happened?

Become familiar with the color change by doing the Quality Control Procedure.

2. Should I worry if my water site has very low alkalinity?

Some areas will naturally have low alkalinity. This might be true in mountain streams. The waters have not contacted rocks or soil long enough for the rocks to dissolve. This just means that these areas are more sensitive to acid additions.

Alkalinity Protocol – Looking at the Data

Are the Data Reasonable?

Alkalinity values range from close to 0.0 ppm to more than 500 ppm, although most water bodies will have values between 40-300 ppm. Discovering unusual values in the data often depends on knowledge of typical patterns at a site. If a site has been measured with almost no alkalinity for many months, then suddenly has 300 ppm, students should recognize a deviation from the normal pattern and investigate further. Other sites may naturally have large swings in alkalinity in response to precipitation, snowmelt, or other inputs into the system.

What Do the Scientists Look for in the Data?

Scientists are interested in how well a water body may be buffered against acid input. Streams with naturally low alkalinity are more sensitive. The pH may drop dangerously low with a relatively small acid input. Scientists would also be interested in investigating areas that show large swings in alkalinity. These areas may be receiving very large amounts of acid. Even though a stream has alkalinity to help buffer the acid input, alkalinity will eventually be neutralized by the acid, resulting in a lower pH.

Example of a Student Research Project

Forming a Hypothesis

A student is looking at the alkalinity data from SWS-02 at Crescent Elk School in California. This water body is Elk Creek, a small freshwater creek. She notices that although there is a lot of scatter in the data, the values seem to be highest in the summer, and lowest in the winter. She knows that precipitation can sometimes affect alkalinity, so she plots rainfall and alkalinity as stacked graphs, shown in Figure HY-AL-1. Precipitation is clearly highest from November through March, and lowest in July and August.

She forms her hypothesis: *In Elk Creek, alkalinity is highest when rainfall is lowest and alkalinity is lowest when rainfall is highest.*

Collecting Data

The student examines the daily data. Three of the alkalinity data points seem very low. On August 15, 1997 the reported alkalinity was 1 mg/L and on September 15 and September 18 1998 it was 9 mg/L. These values seem very low compared to the rest of the values. However, she decides to go ahead with her analysis and hope the data are correct.

She wants to eliminate some of the noise (scatter) in the plot in order to see the relationship more clearly. She plots the monthly average total rainfall and average alkalinity for the five full years of the record, 1997-2001. See Figure HY-AL-2. She then downloads the monthly data (total rainfall, number of days rainfall was measured, average alkalinity and number of days alkalinity was measured) and imports them into a spreadsheet.

Analyzing Data

The student notices that not all months had rainfall data recorded every day. Instead of looking at total rainfall for each month, she decides it will be more appropriate to look at the average rainfall per day. By doing this, she assumes that any missing days will have about the same amount of average rainfall as the rest of the days of the month. She calculates the average by dividing the total amount of rainfall (mm) by the number of days the measurement was reported. [For example, the total precipitation in April 1997 was 113.4 mm, measurements were reported on 30 days, and so the average precipitation was 3.78 mm/day].

Then she eliminates months for which there is no value for either total precipitation or average alkalinity. Six of the 60 months have no average alkalinity data, 3 months have no total precipitation data, and 1 month, Oct-2001, does not have either. After she does this, she has 50 months left of data.

She sorts her data by precipitation as shown in Table HY-AL-1 and then calculates the average precipitation and alkalinity for each 10-month block. The ten months with the highest average rainfall include one November, two Decembers, three Januarys, three Februarys and a March, with an average rainfall rate of 12.7 mm/day. Alkalinity ranges from 55 to 72 ppm, with an average of 66 during these months. As rainfall decreases for the next three sets of months (from 5.5 to 3.3 to 1.4 mm/day), the 10-month average alkalinity is in the 70s: 74, 79 and 76 mg/L. During the 10 months with the lowest precipitation (10-month average only 0.1 mm/ day), the alkalinity ranges from 66 to 99, with an average of 86 mg/L. These months include one June, three Julys, four Augusts, and two Septembers. So, she is satisfied that, on average, the alkalinity is higher during months with very little rainfall than it is during months with high rainfall.

Next, she takes the same data and sorts them by alkalinity rather than rainfall, and again calculates 10-month averages, as shown in Table HY-AL-2. The sorted 10-month averages show a good trend. For average alkalinities of 94, 81,75, 70 and 61 mg/L, the average rainfall is 1.6, 2.7, 3.5, 6.5 and 8.7 mm/day, respectively. Most of the ten highest alkalinities occur from June through September, although there is one March and one April. Monthly average rainfall associated with the 10 highest transparencies range form 0.0 to 4.4 mm/day. Eight of the 10 lowest alkalinities were recorded from November to March; the other two months were in May and in August, both of which had low rainfall. Monthly average rainfall ranges from 0.0 to 16.9 mm/day (the lowest and highest values) despite the high 10-month average.

The student feels she has enough data to support her hypothesis. She prints out her plots and tables and writes her results as a report and submits it to the GLOBE Web site under *Student Investigations*.

Further Thoughts and Future Research

There are some other aspects this student needs to consider. To what extent is the stream affected by snowmelt? How much does snowfall contribute to total precipitation in this watershed? How might the snowmelt during the spring affect the alkalinity even in months with little rainfall?

This site has fairly low alkalinity all year long (less than 100 mg/L as $CaCO_3$). Would a site with higher alkalinity show as much change? How about a site with more seasonal precipitation?

Figure HY-AL-1

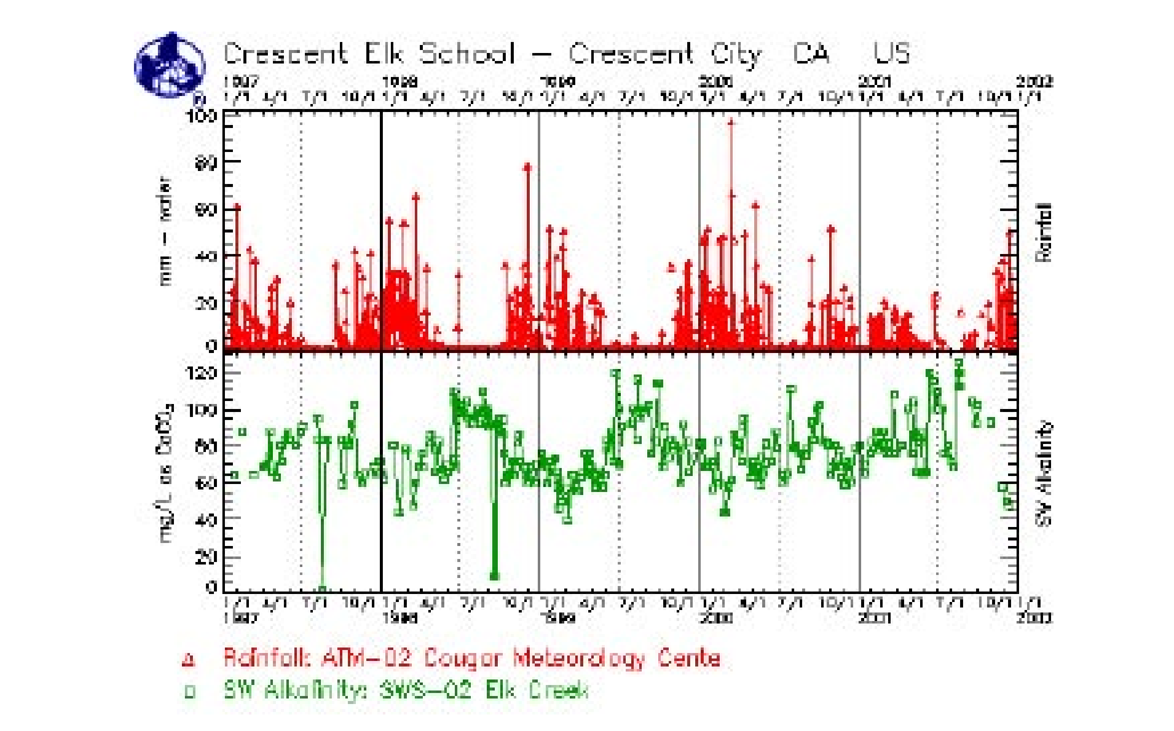

Figure HY-AL-2

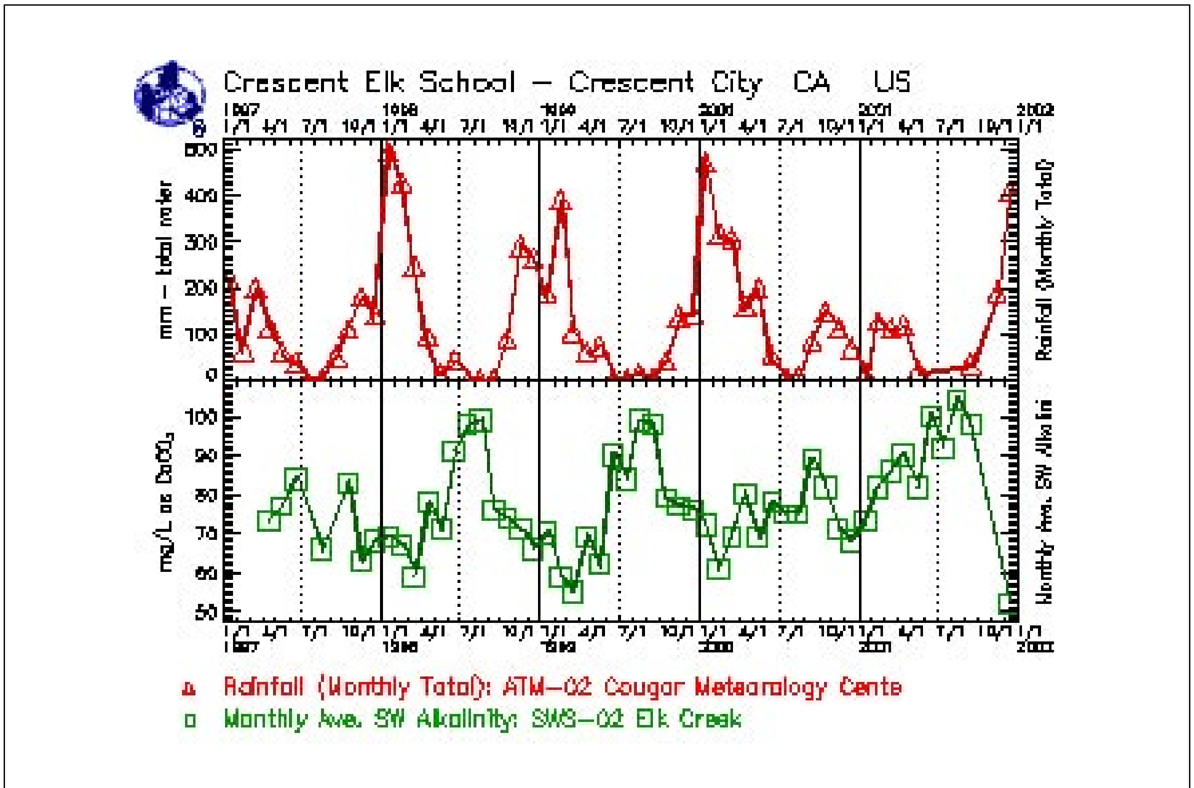

Table HY-AL-1:

1997-2001 Monthly Average Rainfall and Alkalinity, Sorted By Descending Average Rainfall

Month	Average Daily Rainfall (mm/day)	10-Month Average Rainfall	Average Alkalinity (mg/L as $CaCO_3$)	10-Month Average Alkalinity	Month	Average Daily Rainfall (mm/day)	10-Month Average Rainfall	Average Alkalinity (mg/L as $CaCO_3$)	10-Month Average Alkalinity
Dec-01	16.9	12.7	52	66	May-99	2.3	1.4	62	76
Jan-98	16.0		69		Dec-00	2.2		68	
Feb-98	15.8		67		Apr-99	1.9		69	
Jan-00	15.2		72		Jun-00	1.8		78	
Feb-99	13.9		59		Oct-99	1.5		79	
Feb-00	10.9		61		Jun-98	1.4		91	
Nov-98	10.7		71		Jun-97	1.4		84	
Mar-00	10.2		69		May-01	0.8		82	
Jan-99	9.0		70		May-98	0.4		71	
Dec-98	8.8		66		Jan-01	0.4		73	
Mar-98	7.7	5.5	59	74	Aug-99	0.4	0.1	99	86
May-00	6.4		69		Aug-00	0.3		75	
Nov-97	6.4		63		Jun-99	0.2		90	
Apr-00	5.3		80		Sep-99	0.1		98	
Nov-99	5.3		77		Jul-00	0.1		75	
Dec-99	4.9		76		Jul-99	0.0		84	
Oct-00	4.9		82		Aug-97	0.0		66	
Dec-97	4.7		68		Jul-98	0.0		98	
Feb-01	4.5		82		Aug-98	0.0		99	
Mar-01	4.4		86		Sep-98	0.0		76	
Mar-99	4.3	3.3	55	79					
Apr-01	3.9		90						
Apr-97	3.8		73						
Nov-00	3.7		71						
Oct-97	3.5		83						
Oct-98	3.2		74						
Apr-98	3.1		78						
Sep-00	2.8		89						
Sep-01	2.4		98						
May-97	2.3		77						

Table HY-AL-2:
1997-2001 Monthly Average Rainfall and Alkalinity, Sorted By Descending Alkalinity

Month	Average Daily Rainfall (mm/day)	10-Month Average Rainfall	Average Alkalinity (mg/L as $CaCO_3$)	10-Month Average Alkalinity	Month	Average Daily Rainfall (mm/day)	10-Month Average Rainfall	Average Alkalinity (mg/L as $CaCO_3$)	10-Month Average Alkalinity
Aug-99	0.4	1.6	99	94	Nov-98	10.7	6.5	71	70
Aug-98	0.0		99		Nov-00	3.7		71	
Sep-01	2.4		98		May-98	0.4		71	
Sep-99	0.1		98		Jan-99	9.0		70	
Jul-98	0.0		98		Jan-98	16.0		69	
Jun-98	1.4		91		Mar-00	10.2		69	
Apr-01	3.9		90		May-00	6.4		69	
Jun-99	0.2		90		Apr-99	1.9		69	
Sep-00	2.8		89		Dec-97	4.7		68	
Mar-01	4.4		86		Dec-00	2.2		68	
Jun-97	1.4	2.7	84	81	Feb-98	15.8	8.7	67	61
Jul-99	0.0		84		Dec-98	8.8		66	
Oct-97	3.5		83		Aug-97	0.0		66	
Oct-00	4.9		82		Nov-97	6.4		63	
Feb-01	4.5		82		May-99	2.3		62	
May-01	0.8		82		Feb-00	10.9		61	
Apr-00	5.3		80		Feb-99	13.9		59	
Oct-99	1.5		79		Mar-98	7.7		59	
Apr-98	3.1		78		Mar-99	4.3		55	
Jun-00	1.8		78		Dec-01	16.9		52	
Nov-99	5.3	3.5	77	75					
May-97	2.3		77						
Dec-99	4.9		76						
Sep-98	0.0		76						
Aug-00	0.3		75						
Jul-00	0.1		75						
Oct-98	3.2		74						
Apr-97	3.8		73						
Jan-01	0.4		73						
Jan-00	15.2		72						